INTEGRATING ROBOTICS TO DEVELOP PROBLEM BASED LEARNING SKILLS

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Abstract

This study evaluated the employment of the problem-based learning approach integrating robotics as tools within the teaching and learning process. The BeeBots, pre-programmable floor robots, were used as cognitive-learning tools in order to examine students' development of problem-based learning skills: creativity-innovation, critical thinking, and collaboration. A case study approach was employed, collecting quantitative (from 3 different questionnaires, as well as pre- and post- questionnaires) and qualitative data (focus groups). Classroom interventions were designed and implemented during the October – November 2013 time period. The paper presents the background and design of research as well as perceived, indicative results.

Introduction

The idea of robotics integration in education has been around for more than 20 years (Miglino, Lund, & Cardaci, 1999; Papert, 1980). However, the great revolution in the field of educational robotics has been achieved throughout the last decade, where robotics escaped the laboratory and made efforts to connect to education (Chambers, & Carbonaro, 2003). The robotics materials (building blogs/ bricks, sensors and motors), which are perceived as toys by the children, and the educational activities designed using robotics materials bring the students closer to technology as well as challenge their relationship with it (Chambers & Carbonaro, 2003; Williams & Prejean, 2010). Numerous research studies suggest that robotics integration for educational purposes is an effective teaching method, arguing that if robotics activities are appropriately designed and implemented, they have great potential to significantly improve and enhance the teaching and learning process (Bauerle, & Gallagher, 2003; Papert, 1993). It has been shown that no age is too young for being engaged with robotics activities, and, regardless of age, educational background and interests, students consider working with robots to be "fun" and "interesting."

Problem-based learning (PBL) can be defined as an instructional method characterized by the use of *authentic* problem sets as contexts for students to develop critical thinking and problem solving skills and acquire the necessary course concepts. Usually robotics activities are related to addressing a problem, and sometimes problems in authentic, real situations. The students are given a driving question and are requested to program the robots in order to perform a number of activities. Having noticed this connection, the current study aims to bring together the PBL approach and robotics integration in the educational settings, in order to examine if the employment of robotics promotes the development of specific problem-based skills.

Main Aim

This study attempts to evaluate the integration of robotics as an educational tool within the teaching and learning process in relation to the development of students' problem-based learning skills: creativity - innovation, critical thinking, and collaboration (team work). Specifically, the pre-programmable floor robots, the BeeBots were used as cognitive-learning tools in order to apply the problem-based learning (PBL) approach with lower elementary level students (2nd and 3rd graders) in various subject matters (interdisciplinarity). Additionally, the study aims to examine whether through the employment of the PBL approach, where robotics are integrated as tools, it is possible to enhance and further develop the aforementioned students' PBL skills. Through this research study, the researchers and teachers aimed to design learning environments for students to learn by having fun and enjoy themselves. The paper presents the background and design of research as well as perceived, indicative results since the researchers are in the process of analyzing the data collected.

Literature Review

Problem-based Learning (PBL)

Problem based learning is defined as "a systematic teaching method that engages students in learning knowledge and skills through an extended inquiry process structured around complex, authentic questions and carefully designed products and tasks" (Markham, 2003,p. 4). Additionally, PBL is described as the approach that challenges students to learn through engagement in a real problem or situation (Domin, 1999; Duch, 1995). Along the same lines, Grant (2009) defined PBL as an approach to instruction that focuses on "authentic learning tasks grounded in the personal interests of learners" (p. 1). PBL presents students with real-world, multidisciplinary problems that demand critical thinking, engagement, and collaboration.

The main principle of PBL is for students to play the role of problem-solvers and develop critical thinking abilities, knowledge acquisition, decision making, team work and productive collaboration skills, self-evaluation, and flexibility to accept the change (Ryan & Quinn, 1994). PBL is considered as an increasingly essential part of education reform around the world. Larmer and Mergendoller (2010) suggested that for a PBL project to be meaningful it needs to fulfill two criteria: (a) the students need to perceive it as personally meaningful, as a task that matters and that they want to do well; and (b) fulfill an educational purpose with the achievement of specific learning objectives. Additionally, they identified seven essentials parameters that should be taken into consideration when designing a problem-based learning environment. Those parameters are: (1) significant content, (2) a need to know, (3) a driving question, (4) student voice and choice, (5) 21st century skills, (6) inquiry and innovation, and (7) feedback and revision. More specifically, the PBL process requires specific steps to be followed. Initially the educator presents the problem, then the students explore the involved learning issues, and they define possible problems. The next step involves group work where the students investigate potential solutions by researching prior and new knowledge essential for solution finding. Finally they document their problem solution (see Figure 1).

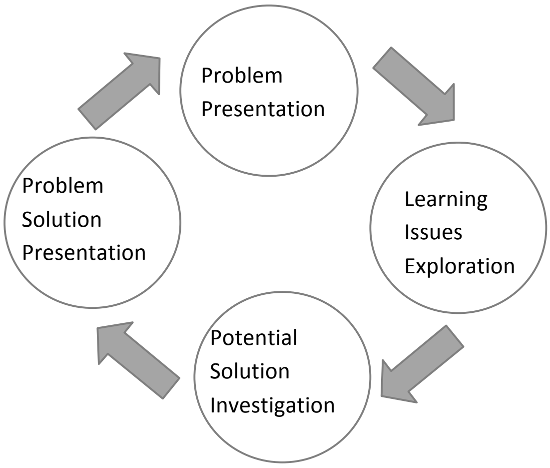

Figure 1. Problem-based learning process.

The educator's role in the PBL process is to guide, support, and facilitate students' initiatives. It is important for educators who decide to incorporate PBL in their courses to realize that students are responsible for their learning and at the same time help their students realize the importance of taking responsibility and control for their learning. More specifically, students will develop with the educator relevant and meaningful assessments for high quality work. Assessments must be meaningful by having connections to the real world (Purser, 2010).

Robotics

Research has shown that robotics integration in education promotes the development of student higher-order thinking skills such as application, synthesis, evaluation, problem solving, decision making, and scientific investigation (Bers, Ponte, Juelich, Viera, & Schenker, 2002; Chambers & Carbonaro, 2003; Resnick, Berg, & Eisenberg, 2000). However in order to achieve the above, robotics need to be integrated as tools and not as subject matter in the educational practice.

When robotics is integrated as a subject matter, as an autonomous entity, and not within a well-designed lesson plan, there is limited educational potential and value. On the other hand, robotics integration as a learning tool, in selected teaching cases, exploits its full potential; therefore it upgrades and enhances the teaching and learning process and promotes school transformation (Eteokleous, Demetriou, & Lambrou, 2013). The intention of this approach is not to learn how to use the robotics package and its programming software, but to use it as a tool within a specific educational context to achieve learning objectives. In other words, robotics is employed as a tool to teach and deliver concepts within various subject matters such as Mathematics, Engineering, Science, Physics, and even in non-technology related fields such as Biology and Psychology (Bers et al., 2002; Eguchi, 2007; Eteokleous et al., 2013). *Robotics integration* in the teaching and learning practice is defined as the use of robotics by students as a tool that enhances their learning experience and supports the achievement of specific learning goals (Eteokleous et al., 2013).

This approach is related to learning *with* computers or *computers as mindtools* (Jonassen, 1999a), where computers and overall technology is introduced as students' partners within the teaching and learning process. Learning with technology requires integrating computers and overall technology as mindtools in the classrooms to support constructive learning. Educators embed technology capacity in the context of ongoing teaching and learning in different school subjects. Thus, students learn how to use technology not as an end in itself, but as a tool that helps them execute their tasks and promotes the balanced development of their mental abilities. As a result they do not learn from technology, but technologies support meaning generated by students (Becker, 1993; Becker & Ravitz, 2001; Bielaczyc & Collins, 1999; CTGV, 2003; Cuban & Pea, 1998; Earle, 2002; Haugland, 2000; Jonassen, 1999a, 1999b; Salomon, Perkins, & Globerson, 1991).

The BeeBot and the Floor Mats

This colorful, easy-to-operate, and friendly little robot, the BeeBot, is a perfect tool for having fun by experiencing sequencing, estimation, problem-solving, and much, much more. More specifically, the BeeBot is a simple and child friendly programmable floor robot that helps children experience introductory concepts related to directional language, programming and control. It can be programmed to move forward and backward for 15 centimetres and to turn 90^0 right and left. The robot can store up to 43 steps. It has also the *pause* button, which is considered as a step. The activities designated to be performed by the BeeBot involve the students in the extremely interesting process of programming robots. They can be programmed in order to perform various educational exercises using specific floor mats (i.e., Greek and English alphabet mat, geometry shapes map, Treasure Island map). The floor mats go hand in hand with the BeeBot. Thus they are as necessary as the robot in order to perform any kind of activity. BeeBot related activities, besides being enjoyable and creative, promote learning by playing and, specifically, the development of various higher order skills. The students examine various concepts by programming the BeeBot, having the chance to develop various knowledge and skills through the process of programming. The students experience the multifaceted processes of problem solving and decision making, as well as cultivate collaborative and exploration skills. For example, the BeeBot can be programmed to "study" geometry shapes, to "study" the alphabet, the colours and various sizes, to "go" for treasure hunting, to "go" for shopping, to "visit" the zoo, to "travel" to different countries.

Research Methodology

A case study approach was employed in order to achieve the scope of the study, mainly collecting quantitative and qualitative data. Classroom interventions were designed and implemented during October – November 2013 in two classes: the 2nd and 3rd grades. The population of the study was 43 primary education students: 21 2nd graders and 22 3rd graders. Two different elementary school teachers were responsible for the lessons' delivery: one teacher for the 2nd grade and another teacher for the 3rd grade. However, the two teachers and the researchers closely collaborated in designing and delivering the lessons in both classes. In both classes the classroom intervention duration was five weeks and involved various subject matters (interdisciplinarity). Specifically, for the intervention in the 2nd grade the subject matters involved were: Mathematics, Arts, Geography and Health Education. For the classroom intervention in the 3rd grade the subject matters involved were: Language and Linguistic Course and Arts. In both grades, during the Arts course the students developed the floor mats to be used with the BeeBots. The students worked in groups to develop a total of five floor mats. All students contributed in the development of the floor mats. The 2nd graders developed the following two floor mats: (a) Solid Shapes and (b) Our School Map, and the 3rd graders developed the following three floor maps: (a) The Alphabet, (b) the Word Search Puzzle, and (c) Professions of the Past. See Table 1 for a list of the maps and Figures 2-5 for illustrations.

Table 1

The Floor Mats Developed By Students: Five-stage Model for Integration

Grade	Subject Matter	Floor Mats
2nd	Mathematics	Solid Shapes
	Language and Linguistics	Our School Map
	Arts	*Developed the floor mats*
3rd	Language and Linguistics	The Alphabet
		Word Search Puzzle
		Professions of the Past
	Arts	*Developed the floor mats*

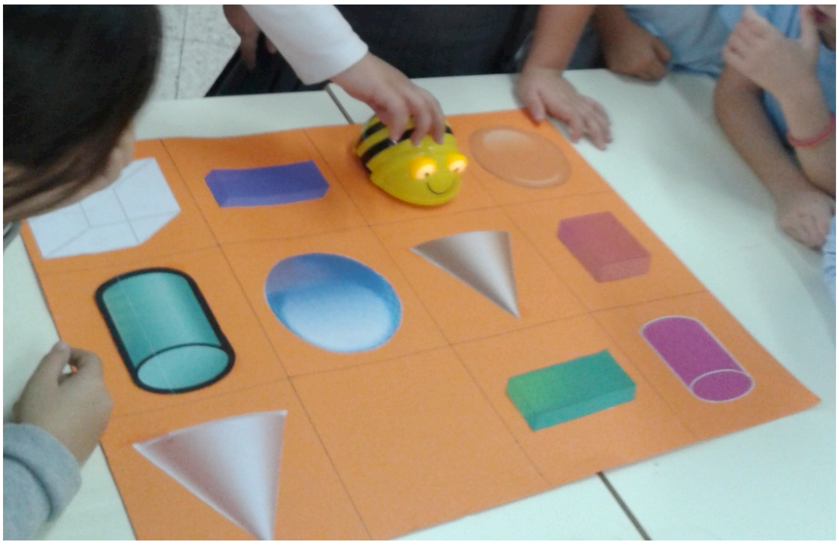

Figure 2. Floor mat: Solid Shapes.


Figure 3. Floor mat: Our School Map.


Figure 4. Floor mat: Word Search Puzzle

Figure 5. Floor mat: Professions of the Past

Questionnaires, observations and focus groups with the students were the main methods of data collection. Three different questionnaires were given to students for completion. Each questionnaire measured different problem-based learning skills: (a) innovation - creativity, (b) collaboration (team work) and (c) critical thinking. The questionnaires employed were taken from the Buck Institute of Education (www.bie.org) and were adjusted for the purposes of this study. The questionnaires were translated into Greek and pilot tested. Specifically, two teachers participated in the pilot study (the ones that their students used the BeeBots) and five students: two 2nd graders and three 3rd graders. The authors took into consideration the teachers' and students' comments and adjusted the questionnaires accordingly in order to meet the needs of the students. Pre- and post- questionnaires were given to students.

The instruments. As noted, three questionnaires were used for data collection (see Table 2). The questionnaires were different for each grade due to the age of the students (as suggested by the Buck Institute of Education). For the second graders the simplest form of questionnaire was used, employing a combination of smiley / sad faces and phrases (as responses). For the 3rd graders a different form of questionnaire was used, a more complicated one, as suggested by the Buck Institute of Education. See Table 2 for details.

Table 2

The PBL Skills Questionnaires

Grade	Questionnaires	Parameters	Questions	Question Type
2nd	Critical Thinking		6	3 point - Likert scale
	Collaboration		5	
	Innovation – Creativity		6	
3rd	Critical Thinking (4)	Analyzing driving question and begin inquiry	2	5 point - Likert scale
		Gather and evaluate information	2	
		Use evidence and criteria	3	
		Justify choices	2	
	Collaboration (6)	Takes responsibility	4	
		Helps the team	4	
		Respects others	2	
		Makes and follows arrangements	4	
		Organizes work	2	
		Works as a whole team		
	Innovation – Creativity (4)	Define the creative challenge	1	
		Identify resources of information	1	
		Generate and select ideas	4	
		Present work to others	1	

As Table 2 illustrates, the critical thinking questionnaire for the 2nd grade consisted of six questions, the collaboration questionnaire included five questions and the creativity-innovation questionnaire six questions. For the 3rd grade, the critical thinking questionnaire consisted of four parameters and a total of nine questions; the collaboration questionnaire consisted of six parameters and a total of sixteen questions; and the creativity - innovation questionnaire consisted of four parameters and a total of seven questions.

Observations were conducted throughout all lessons delivered in order to record and evaluate the process of developing the floor mats and programming the BeeBots aiming to "solve" the problem given. Additionally, four focus groups were conducted (two for each grade) when the classroom interventions were completed with a total of fifteen students participating: seven 2nd grade students and eight 3rd grade students. The students were selected on a voluntarily basis. The data collection process took place in October-December 2013 and the authors are in the process of analyzing the data collected.

Preliminary Results

Since the authors are in the process of analyzing the data collected, perceived results are summarized in this section. The initial analysis of the pre- and post-questionnaires revealed the development of the creativity-innovation and the critical thinking skills for both the 2nd and the 3rd grades. However, the collaboration (team work) skills were not developed as much as the creativity-innovation and critical thinking skills. This is due to minor conflicts observed within the teams while trying to program the BeeBots. Students were so excited in using the BeeBots that the majority of them were very anxious in holding, touching, and programming the BeeBots. In some cases it was impossible to have turns in using the BeeBots.

The observations showed that during the courses where the BeeBots were integrated as tools for the performance of activities more time was needed than the allocated time for each teaching period (40 minutes). The aforementioned was observed in almost all courses (i.e., Maths, Health Education, Language and Linguistics) besides the Arts (where students needed to develop the floor mats). Additionally, the presence of a teacher assistant deemed necessary in order to help the teacher follow the teaching plan developed in terms of the activities, resolve any problems revealed (i.e., conflicts within groups), appropriately guide, and facilitate the teaching and learning process. Also, observations revealed that although students followed the directions given by the teachers and addressed the exercises and problems given, they wanted to be granted time to "play" with the BeeBot. Students were asked during the focus groups about the aforementioned phenomenon observed. They commented that they wanted to develop their own activities and problems for their classmates to address. They wanted to develop their own paths for the BeeBot to follow. Finally, during the focus groups, the majority of the students reported that the BeeBot experience was extremely enjoyable and very interesting, since learning was achieved through playing. A major suggestion given was the need to have more BeeBots and instead of 3-4 members in each group, it is better to have groups of two students only.

Conclusion

There is a great potential of integrating robotics as a learning tool to achieve specific learning objectives as well as increase students' knowledge and skills. This study adds to the relatively new body of literature related to robotics integration as within the teaching and learning practice. Additionally, it provides the foundation to further examine robotics' role in enhancing the educational practice and students' experiences and in promoting the development of students' problem-based learning skills: critical thinking, creativity, and collaboration (team work). The study results indicate the need to promote research in the field of educational robotics in order to further examine and define appropriate learning pedagogies and teaching approaches to be employed when robotics is integrated within classroom activities.

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